# 6.2: A 10-in. Surface-Conduction Electron-Emitter Display

*E. Yamaguchi, K. Sakai, I. Nomura, T. Ono, M. Yamanobe, N. Abe, T. Hara, K. Hatanaka, Y. Osada, H. Yamamoto, T. Nakagiri*
Canon Research Center, Kanagawa, Japan

## Abstract

**A 10-in. flat panel display (FPD) with surface conduction electron emitter (SCE) cathodes can be fabricated through a printing process. Ultrafine particle films of the SCEs are deposited by using an ink jet printing. A prototype achieves full color and full motion pictures, comparable to CRTs. The feasibility of larger and low cost SCE displays has been confirmed.**

## Introduction

Recently, we proposed a new SCE cathode for FPDs and an architecture of the surface conduction electron emitter display (SED)[1]. The SED has many advantages, which are simple structure, easy driving, high luminance and good color. These merits were shown using a 3.1-in. prototype.

The SED has a potential to develop a large-screen FPD, because the cathode structure and the panel structure are so simple that the fabrication process is not difficult. The key for a large-screen SED is a fabrication of the large SCE cathode plate. The points are that an electron emitting region is made through an energizing forming process of an ultrafine particle thin film, and that the connecting matrix wires with the low electrical resistance and capacitance must be prepared for the easy driving.

In this paper, we show a construction of SCE cathodes which are fabricated through a printing process. The ultrafine particle film of the SCE is fabricated through a ink jet (bubble jet[2], BJ) printing process, which is a good process for making the thin and small sized film. In addition, a conventional screen printing process is used to fabricate the connecting matrix wires with the low resistance and capacitance. The printing process are treated in the air, not in the vacuum, so it enables high through-put and low cost.

A 10-in. SED with the cathode plate manufactured by the printing processes is demonstrated. The prototype achieved high image quality with full motion and full color pictures comparable to CRTs. And the power consumption of the prototype was low enough for a large-screen FPD.

## An Architecture for a Large-Screen SED

A construction of the large-screen SED is simple as follows. The SCEs cathode plate and the high voltage anode plate with conventional CRT phosphors are separated by many spacers, which allow vacuum without the change in the tight spacing. The cross structure for a pixel is schematically shown in Fig.1.

The SCE cathode is made of ultrafine particle films of palladium oxide (PdO), pairs of electrodes and simply connected matrix wires. Such a simple and plane device structure enables to use printing process (that is relatively rough


ISSN0097-0966X/97/2801-0052-$1.00 + .00 © 1997 SID

precision comparing to photo-lithography process) for fabrication.

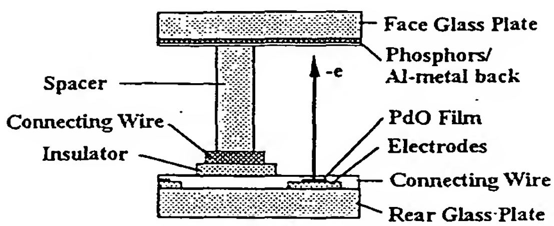


FIG.1 Schematic cross section of one pixel of the large-screen SED

The PdO Film by Ink Jet Printing

The schematic diagram of fabricating the PdO film by using the ink jet printing process is shown in Fig.2. The ink jet printing head is scanned mechanically over the glass substrate, the ink droplet containing solution Pd is ejected and placed in just a position above the electrodes. We used a BJ printing head (manufactured by Canon Inc.) as an ink jet head. Then the substrate is fired in an oven.

Applying the ink jet printing process to fabricate the SCE films adds the following merits.

1) Micro Droplets

The ink jet printing process has the ability to generate very small droplets, which allows very thin film thickness (~10nm) and a small PdO film area(~100um), which is suitable for making the electron emitting region by the forming.

2) Processing in the Air

The process needs neither a vacuum nor a special atmosphere. No vacuum leads short process time and easy handling in comparison to a conventional semiconductor fabrication process (sputtering and so on). So the fabrication equipment can be quite simple and low cost.

3) Low Consumption of Materials

Printing processes need just an amount of printed material. The consumption of materials is lower than in the semiconductor fabrication processes, which involve deposition, photo-lithography and etching processes. Thus the process is economical.

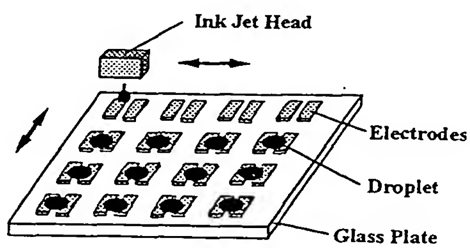


FIG.2 Schematic diagram of the PdO fabrication process by using ink jet printing

Electrodes and Matrix Wires by Printing

We have used conventional printing technology for making electrodes and matrix wires.

For example, matrix wires are printed by using screen printing. Column lines, an insulator pattern and row lines are printed as the thick film. The ink for the conductive lines consists of Ag, PbO, resin and solvent. The ink for the insulators is consists of PbO, resin and solvent. The matrix wires, without short and/or open, are fabricated reproducibly and with good yield. Because of thick film structures, the electrical resistance of wires and the capacitance at the crossing point of the matrix wires are lower than that of matrix wires fabricated by photo-lithography and etching process. This reduces the driving difficulties for the displays.

### A 10-in Prototype

Specification

We have made a 10-in-diagonal prototype with 240x240x3 pixels. The thin spacers were placed on the screen printed wires to avoid disturbance of the electron path. The spacer size was 40mmx3mmx0.2mm. As a result of structural simulation, we used 28 pieces of spacer arranged with an appropriate distance. These were sealed by frit glass with the frame and the anode plate to maintain the vacuum. The thickness of the panel is 8.6mm, which is the sum of 2.8mm cathode plate, 2.8mm anode plate and 3mm vacuum spacing. Its weight is 1.4kg. The anode plate has stripe-patterned P-22 (R/G/B) phosphors and black stripes covered with a metal backing film.

The SCE cathode plate was made as follows: the matrix wires through screen printing and the PdO film by ink jet printing. A photograph of the SCE cathode plate made through above described printing process is shown in Fig.3. The PdO film, the platinum electrodes and matrix wires can be arranged with sufficient tolerance through the printing process.

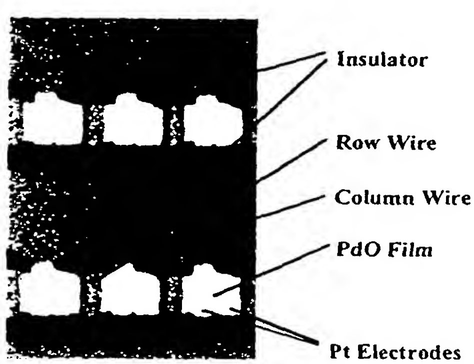


FIG.3 A photograph of the printed matrix wired SCE cathode glass plate

Characteristics

Fig.4 shows the characteristic of gray scale generation when driving the display with pulse width modulation. White luminance of 690cd/m$^2$ and a contrast ratio >1000:1 were obtained at 15V driving voltage (Vf) and 6kV anode voltage (Va). The prototype has good linearity at a 60Hz frame rate, resulting from high speed response of the SCEs and low capacitance load of the printed matrix wires. It shows that the SED generates high luminance and full motion pictures comparable to conventional CRTs. The performance of the panel are shown in Table1

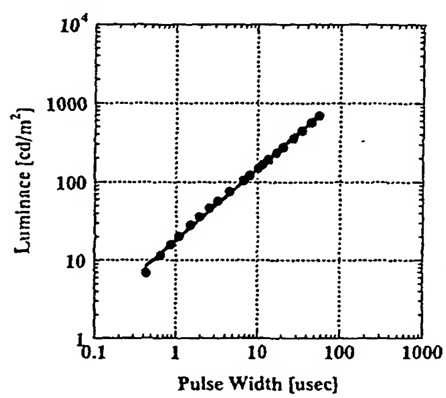


FIG.4 Luminance as a function of pulse width for the prototype

| | |
|---|---|
| Screen Size | 156x208.8 mm (10-in.-diagonal) |
| Pixel Pitch | 0.65x0.29 mm |
| Number of Pixels | 240x240x3 |
| Color Arrangement | RGB-Stripe |
| Phosphors | P22 |
| Driving Voltage | 15V |
| Anode Voltage | 6kV |
| Luminace | 690cd/m$^2$ |
| Gray Scale Levels | 256 |
| Contrast Ratio | >1000:1 |
| Thickness | 9.6mm |
| Weight | 1.4kg |

Table1 Performance of the prototype

Fig.5 shows the chromaticity dependence on the pulse width. The measured chromaticity of each color is consistent with P22 phosphor for conventional color CRTs, and the pulse width dependence is low. Fig.6 shows a NTSC-picture on the prototype. Thus, it is shown that the SED has the ability of stable color generation and of color balance controllability like CRTs.

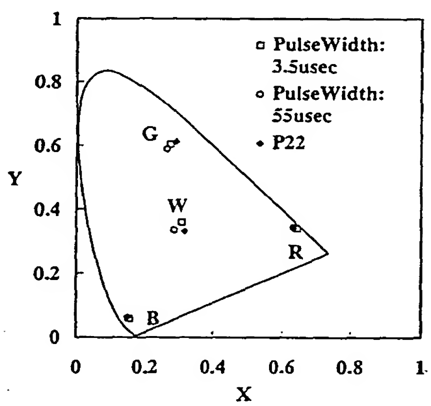


FIG.5 Chromaticity diagram with respect to R,G,B,W as a function of pulse width for the prototype

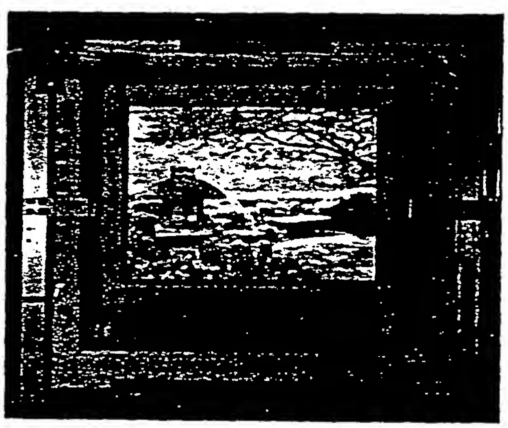

FIG.6 A photograph of a NTSC-picture on the 10-in.-SED prototype

This figure is reproduced in color on page 1121.

For a large-screen SED, we calculated the power consumption. In case of 170cd/m2 of average luminance, it is calculated that the whole power consumption of the prototype was 5.6 watts under Vf=15V, Va=6kV and driving-duty = 0.0033. For a 40-in. SED, it is estimated to be 53W. This is low enough for home use.

Additionally, the accelerating voltage for electrons is less than 10kV, so X-ray radiation from the SED is negligibly low. And no distortion by terrestrial magnetism occurs, because of the short electron path length in contrast with CRTs.

## Conclusion

An architecture for a large SED with the SCE cathodes plate fabricated by printing technology has been shown. We have succeeded to fabricate the SCE cathode through printing process, an ink jet printing for a PdO film and printing for the electrodes and the matrix wires. A 10-in SED prototype shows full color images as good as CRTs. The power consumption is low enough for large FPDs.The feasibility of larger and low cost SEDs by using printing processes has been demonstrated.

## Acknowledgement

The authors would like to thank Noritake Co. for their useful supports.

## References

1) K.Sakai, et al., Euro Display, 18.3L,pp569-572, 1996

2) T.hara and I.Endo, J. Inst. Image Electron Engrs. Jpn, vol.11, pp66-71, 1982 [In Japanese]